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ABSTRACT

Some wind characteristics in the stratosphere during the different seasons of the year are discussed on the basis of measurements obtained by the Meteorological Rocket Network of the USA (1959-1960) and the USSR during the IGY.

The present report is based on a series of wind measurements performed by the Meteorological Rocket Network of the United States in 1959-1960 and on rocket measurements of the wind in the USSR in the stratosphere and the lower mesosphere, during the IGY. The observations in the United States were carried out in the latitudinal region from the tropical latitudes to 65° N (Ref. 1). Observations in the USSR were employed at two points: at O. Kheys (80° N) and at the mean latitudes. Wind measurements in the United States were performed by constructing radio targets in the atmosphere and by tracing them with radar. A cloud of metallized particles or target-parachutes were employed as targets. Rockets were employed to deliver the targets to the requisite altitude. Wind measurements were performed in the USSR by tracking the nose section of a meteorological rocket, which separated from the body close to the trajectory peak and descended in a parachute. The parachute-nose section system was equipped with a radio beacon. The utilization of radar tracking to determine the trajectory elements of the system made it possible to compute the wind velocity and direction. The degree to which the system lagged behind the stream due to its great inertia was thus taken into account. /52*

Wind observations in the stratosphere showed the seasonal nature of the wind direction - its shift from primarily the west (winter) to the east (summer) in a layer above 20 km. The seasonal nature of the wind direction is primarily determined by the cooling processes (winter) and warming processes (summer) of the arctic stratosphere, which changes the picture of the temperature field throughout the entire hemisphere as a whole. The temperature gradient thus changes its direction by approximately 180°. A representation of the change in the wind field provides average seasonal values for wind velocity, which we calculated on the basis of observations derived from the Meteorological Rocket Network of the U.S.A. (Figure 1).

* Note: Numbers in the margin indicate pagination in the original foreign text.

All of the material was distributed according to latitudinal zones: 90-60° northern (I), 60-30° - moderate (II), and 30-0° - southern (III), and according to seasons. Three calendar months (winter - December, January, February, etc.) were included in each season. Easterly winds, with a maximum of the eastern component at 50-60 km, predominated in the summer in all zones. In winter, westerly winds were stronger, particularly in the mean latitudes, with a maximum at an altitude of not less than 60 km. At high latitudes, the maximum apparently lies below approximately 45 km. The mean data compiled in the fall point to the fact that - if the wind distribution is close to the winter distribution at this time in the mean and low latitudes - the northwestern direction predominates in the northern zone. This points to the non-zonal distribution of isohypses (isotherms).

It is apparently useless to expect a zonal distribution of meteorological elements close to the pole in autumn and winter, because zonality on the earth and in the atmosphere is determined by the zonality of solar radiation. On the other hand, the large meridian contrasts in regions /53
close to the poles (the ice mass of the Canadian archipelago - Greenland, the warm Atlantic, the cold north of Siberia, and the warmth of the Pacific Ocean) must influence the nature of the distribution in the Polar Zone, thus disturbing the zonality. In the atmosphere this is expressed by the well-known two-center structure in winter of the polar baric system, which was established previously by data derived from probes in the troposphere (Ref. 2). Two low-pressure centers are located on maps showing the baric topography for high elevations (January, 10 mb); one of these centers is located in the direction of the Taimir Peninsula, and the other - above Greenland (Ref. 3). Such a pressure distribution must lead to the nonzonality of air currents in the arctic stratosphere, and it is just this type of distribution which is obtained from data in the fall. Data obtained in the winter do not corroborate this distribution, and it is possible that this is only due to the small number of observations performed in the winter.

The average data obtained in the spring show that, while an easterly /54
wind begins to predominate in the upper and lower latitudes, at the mean latitudes it continues to remain westerly. An explanation of this fact can be found in the upper-air maps of baric topography constructed for the North American continent. It can be seen from these maps that at great altitudes (on the order of 1 mb) the rapid heating of the artic stratosphere leads to a disruption of the polar cyclone, and a trough is located to the north of the middle latitudes. On the southern periphery of this trough, westerly winds continue to be observed (Ref. 4). Thus, during the main seasons the circulation differences between the three zones consist primarily of wind velocities, while in the transitional seasons differences are observed in the direction of the air currents. In spring, a lag in the circulation sign change in the moderate zone, and the beginning of a sign change in the upper levels, are characteristic.

The distribution of the mean wind gradients in the main seasons is an interesting feature. They have the following values in summer and

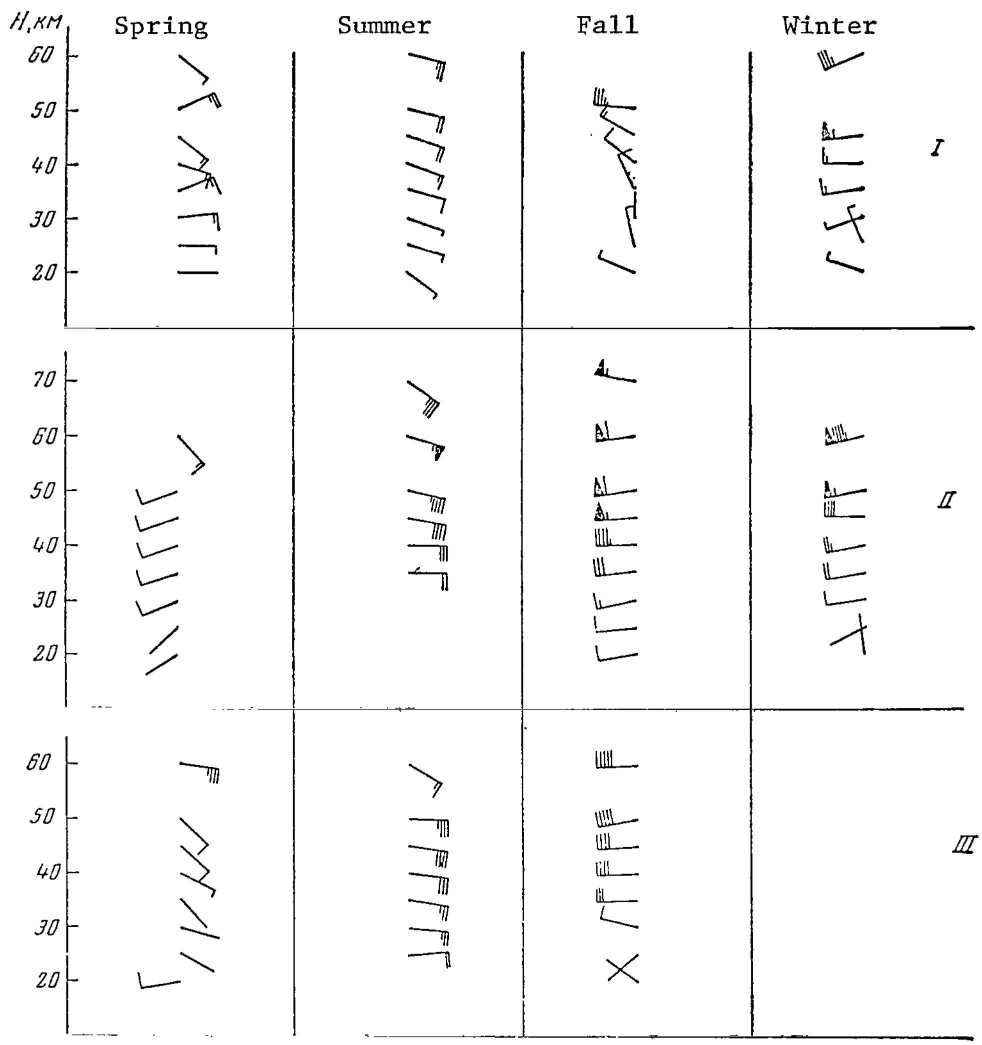

Figure 1

Mean Seasonal Values of Wind Velocity According to Data of the Meteorological Rocket Network of the U.S.A.

I - Northern Zone (60-90° N); II - Moderate Zone (30-60° N); III - Southern Zone (0-30° N)

winter:

H, km	Summer	Winter	H, km	Summer	Winter
65-60	+3.4	+1.2	45-40	-1.4	+1.0
60-55	+0.2	+10.2	40-35	-1.8	+2.8
55-50	-0.8	-1.8	35-30	-1.0	+2.8
50-45	-1.0	+0.8	30-25	-0.2	+1.6

A change in the vertical wind gradient is a distinct and, apparently, regular phenomenon.

In summer all other data point to the existence of the greatest negative wind gradients in the 35-45 km layer. In this layer there is a sharp increase in wind with altitude, which points to great temperature differences in this layer (the north is warmer than the south). In winter, the gradients are also negative in the 50-55 km layer on the overall background of positive gradients at other altitudes. In this layer the temperature gradient must be just the reverse of the mean gradient in the winter - i.e., the north must be warmer than the south. Thus, this material suggests that there is always a layer in the atmosphere whose altitude increases in winter and decreases in summer, where the north is warmer than the south (in the summer, the north is considerably warmer than the south).

This feature can be compared with the distribution of ozone in the stratosphere; the main characteristics of the temperature field for the layer under consideration are determined by the presence of ozone. One difficulty entailed in such a comparison is the lack of data on the vertical ozone distribution, which is very important in the given case. In thermal terms, the most active region of the ozonosphere is located above 30-35 km, while the ozone distribution maximum is located at an altitude of about 25 km. Measurements of the total ozone content provide information on the change in its overall concentration. However, the maximum of the overall content can in no way coincide with an increase in its concentration in the layer above the maximum region. In other words, an increase (or decrease) in the overall concentration in the vertical column does not in any way indicate that it has vertical distribution.

The winter anomalous layer can be explained by a higher ozone concentration in the upper latitudes. In winter (January) the total ozone content changes from 30 to 60° latitude with 210 to 280.10^{-3} cm. Hg - i.e., it increases by approximately 30%. Thus, a diminution of the western currents in winter can be caused by the sign change of the temperature gradient in the ozonosphere region which is thermally most active, at altitudes of 45-55 km.

Changing to summer, we find that the altitude of the layer which is thermally active depends both on the vertical ozone distribution, and on the height of the sun above the horizon. Actually, when the sun is at a higher position its rays from the short-wave portion of the spectrum /55
penetrate the ozonosphere more deeply, moving underneath the boundary of the ultraviolet shade. When the sun is at a lower position, this boundary will be located above.

The well-known relationships connecting the radiation intensity with the amount of atmospheric masses which are penetrated, or with the zenith distance of the sun, show that the seasonal change in the altitude of the layer under consideration can be provided by the annual variation in the height of the sun. Thus, the wind profile - more precisely, the vertical gradient of its zonal component - apparently reflects certain anomalies in the temperature distribution. In their turn, these anomalies are related to the annual variation in the height of the sun and the ozone concentration.

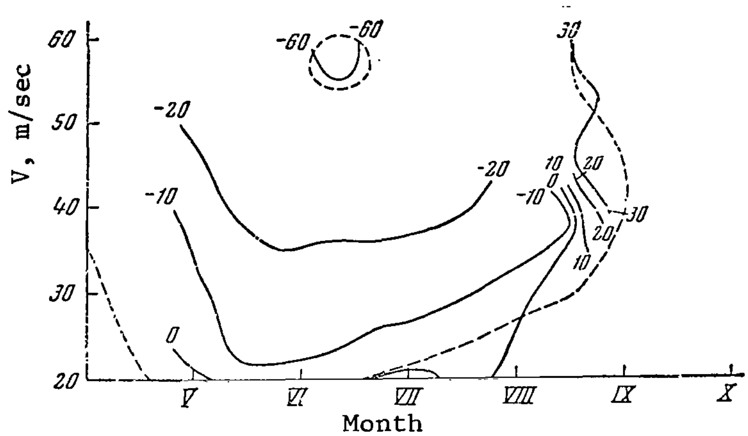

Figure 2

Time Profile of the Zonal Wind Component (1957 Mean Latitudes in USSR)

Minus Sign Corresponds to Eastern Direction

Dotted Line Corresponds to Data of E. S. Batten (Ref. 5).

An atmospheric profile in time was constructed for altitudes from 20 to 50-60 km based on data for the spring-summer-fall of 1957 (Fig. 2). The profile, constructed on the basis of observations over one year and at a single point on the earth, will have local characteristics. At the present time it is difficult to say whether the circulation at these altitudes is the same during different years. We should point out that the profile was formulated on the basis of limited observational data. Eighteen soundings up to different altitudes, encompassing a period from the end of May to October, were used to construct this profile.

It can be clearly seen on the zonal component profile that in spring an easterly wind appears in the atmosphere at the upper level; over a period of time, this wind includes the lower layers down to 20 km. In one and the same level, this is expressed in a gradually-increasing velocity of the eastern component from spring to the middle of summer. The eastern component maximum is reached at an altitude of 60 km, or somewhat higher, approximately in the middle of July (about 60 m/sec). It is impossible to establish the exact time of the maximum due to the limited number of soundings at the upper levels.

Several authors have repeatedly confirmed the fact (Ref. 6) that the vernal reconstruction of the wind field is initiated at the upper levels, and then includes almost the entire stratosphere. This reconstruction corresponds to an analogous reconstruction of the temperature field, which is also initiated at the upper levels. The autumn directional change differs from the vernal change. It can be assumed that the westerly winds penetrate the region of easterly winds both above and below the level at which the easterly winds remain for the longest period (up to the middle of September) - this altitude is close to 40 km.

For purposes of comparison, the corresponding profile lines of E. S. Batten (Ref. 5) (dotted line) for latitudes at 30-40 km were plotted on the profile. The conspicuous coincidence in the distribution of the wind zonal component in these two profiles points to the comparative stability of the wind at mean latitudes above different points on the earth throughout different years. Material for different years was employed in the profile of E. S. Batten, but data from 1959-1960 were employed to a significant extent. The following should be noted among these main forms of agreement: (1) The nature of the wind field reconstruction in spring; (2) The position of the summer wind maximum; (3) The nature of the wind field reconstruction in autumn. /56

The profile differences are as follows: (1) The zonal component velocities, which are smaller on the whole, in the reconstructed profile (for example, the isotach of 20 m/sec in the middle of summer is 6 km higher in our profile; the isotach of 40 m/sec - is 4 km higher); (2) As compared with the profile of Batten, the entire picture is shifted somewhat (by 0.5-1 month) toward the earlier periods, particularly in the transitional seasons. The discrepancies indicated above can be caused by several reasons - namely, time (more correctly, intra-year) and longitudinal differences, as well as the small amount of material utilized by us. However, the existing differences do not invalidate the agreement indicated above.

An analysis of individual cases of wind probes in the stratosphere can reveal several unusual features of the circulation. In the fall and winter of 1958, an easterly wind was detected three times in the stratosphere above the O. Kheys higher than 20 km; wind having a meridian (7) direction was detected once. T. J. Keegan made a detailed study in 1962 (Ref. 7) of the appearance of easterly winds in the winter at mean latitudes in the stratosphere. The appearance of easterly winds in winter at mean latitudes in the stratosphere, above the North American continent, is indicated by the significant shifts in the main centers of action in the stratosphere with respect to their mean position. Thus, according to 10 mb maps the trough of the polar winter cyclone is located above the Labrador Peninsula, and even above the continent in the direction of California, and the crest of the Pacific Ocean anticyclone extends to Alaska. In this way, the baric (and temperature) gradient acquires a direction which is the reverse of the mean direction in winter, which causes a shift in the wind direction. The winter sources of the easterly wind, which were studied by Keegan, have their centers at altitudes of 30-40 km, but their influence can extend up to 50-60 km, i.e., they include almost the entire stratosphere.

Instances showing disturbances in the western circulation in winter at the O. Kheys were compared with baric topographic maps of 100 and 30 mb. The maps showed that in these cases the cold winter cyclone was shifted with respect to the pole, either in the Greenland section of the Atlantic, or in the direction of the Taimir Peninsula. In this way, the region between the pole and the cyclone center was in the zone of eastern circulation, which extends to an altitude of not less than 40 km, which apparently corresponds to the minimum altitude of baric formations, the polar cyclone, and the Aleutian maximum. We should also point out that this altitude coincides with data obtained from observations in the United States (see Figure 1, autumn, northern zone).

Similar synoptic situations must inevitably result in an attenuation of the mean zonal western component at high latitudes, which is observed in actuality.

Shifts in the polar cyclone center, determined from data derived from wind probes and from 30 mb surface maps, are similar in their synoptic nature to those described by S. S. Gaygerov for the winter temperature rise (Ref. 8).

Since the shifts in the cyclone center during winter and spring are caused by one and the same mechanism - and since these shifts acquire a systematic nature in spring - it can be expected that a constant shift /57
in the winter circumpolar cyclone is indicated to a certain extent by the mean atmospheric characteristics in spring at mean latitudes. Actually, at the mean latitudes the velocity of the western component at an altitude of 30 km is larger in April than it is in winter. Thus, a disturbance of the western circulation to the north of the cyclone center and its intensification in the more southern regions accompany the shift in the polar cyclone.

REFERENCES

1. Data Report of the Meteorological Rocket Network, N 1-5. IRIG - MWO, 1960.

2. Pogosyan, Kh. P. Seasonal Fluctuations in the General Atmospheric Circulation (Sezonnyye kolebaniya obshchey tsirkulyatsii atmosfery). Trudy Tsentral'nyy Institut Pogody, No. 1, 1947.

3. Dubentsov, V. R. Air Currents in the Atmosphere (Vozdushnyye techeniya v atmosfere). Meteorologiya i Gidrologiya, No. 11, 1959.

4. Joint Scientific Advisory Group to the Meteorological Rocket Network. J. Geophys. Res., 66, N 9, 1961.

5. Batten, E. S. Wind Systems in the Mesosphere and Lower Ionosphere. J. of Meteorol., 18, N 3, 1961.

6. Scrase, F. J. Radiosonde and Radar Wind, Measurements in the Stratosphere Over the British Isles. Quart. J. Roy. Meteorol. Soc., 77, N 333, 1951.

7. Keegan, T. J. Large-Scale Disturbances of Atmospheric Circulation Between 30 and 70 Kilometers in Winter. J. Geophys. Res., 67, N 5, 1962.

8. Gaygerov, S. S. Problems of Aerological Structure, Circulation, and Climate in the Free Atmosphere of Central Arctic and Antarctic (Voprosy aerologicheskogo stroyeniya, tsirkulyatsii i klimata svobodnoy atmosfery Tsentral'noy Arktiki i Antarktiki). Meteorologiya, No. 4, Seriya "Rezul'taty MGG", Izd-vo AN SSSR, 1962.

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